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ABSTRACT

Reported is a study to: (1) investigate the effects of two junior high science curricula on the acquisition of selected process skills of science, and (2) determine the effects of sex and race on the acquisition of science processes by students. Comparisons were made between performances of students enrolled in Intermediate Science Curriculum Study (ISCS) and Introductory Physical Science (IPS), between male and female students, and between white and non-white students. Scores on the Process of Science Test (POST) were used as the criterion measure. The experimental group consisted of 88 students (67 white, 21 non-white; 47 male, 41 female). The control group was composed of 79 students (65 white, 14 non-white; 41 male, 38 female). All were eighth-grade students who had completed a life science course in seventh grade. There were no significant differences between groups on verbal, math, and science, or abstract reasoning ability for the first equivalence comparison. When analysis of variance was performed with POST scores as criterion and treatment and race as variates, a significant racial effect was observed. Using analysis of covariance, no significant differences between treatment groups, sex groups, or racial groups were identified when ability, math ability, science ability, and abstract reasoning ability were controlled statistically. The investigators concluded that neither IPS nor ISCS-Level II removed racial differences in acquisition of science processes. (Authors/PEB)

Sex, Race, Junior High Curriculum, and the Acquisition of Process Skills

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Objectives

The objectives of this study were: (1) to investigate the effects of two junior high curricula on the acquisition of selected process skills of science and (2) to determine the effects of sex category and race on the acquisition of science processes by students enrolled in ISCS-Level II and IPS science curricula. More specifically the study investigated student performance differences between students enrolled in Intermediate Science in Curriculum Study (ISCS) and Introductory Physical Science (IPS), between male and female students, and between white and non-white students. Scores on the Process Of Science Test (1970) were used as the criterion measure.

Rationale

The IPS curriculum stresses the collection of data by teams of students and the group analysis of the data as a means to formulate conclusions about scientific phenomena. The ISCS-Level II stresses the collection of data using a systems-model approach with emphasis on individual analysis of collected data. Another major difference between IPS and ISCS-Level II is the manner in which the course material is presented. IPS is a group-paced curriculum which suggests teacher led pre-lab discussions followed by lab and teacher-student post-lab discussions to identify trends and conclusions based upon empirical data. In contrast, ISCS-Level II uses an individually-paced format which de-emphasizes the total class interaction in favor of more personal student-teacher interaction. These differences in approach raise the question - will the student having depressed verbal ability - especially the non-white student in this district - be hindered by the lack of specific group direction and the dependence upon verbal skills embodies in the reading needed for continued progress?

With these curricular differences in approach in mind a literature search was conducted to determine what research has shown about classroom environment, non-white achievement, and student achievement in ISCS science. Some studies (e.g. Rippey 1965, Shavelson and Munger 1968, and Babikian 1971) have shown that it is desirable to select a classroom environment that combines laboratory and expository teaching methods with self-paced materials which identify the

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correct procedures and leads the student to the correct answer with chance for small group discussion of the results. The ISCS-Level II curriculum flexibility exhibits these characteristics (except for expository teaching methods) and encourages small group (2-4 students) discussion. The IPS material also meets these criteria with the exception of the self-paced options for students. Using these criteria it might be hypothesized that the ISCS curriculum possesses a slight advantage over IPS.

Inspection of the macro-teaching environment suggests that the self-paced, errorless material with laboratory work is best suited for high student achievement; however, when one investigates learning environments in which non-white students' performance is elevated (Day and George, 1970; George and Dietz, 1971) the advantage appears to rest with a highly structured, teacher-lead environment with extensive student-teacher interaction such as commonly found in IPS classrooms. In its present form it is the author's judgment that the ISCS-Level II curriculum depends extensively on initial verbalization of concepts. It follows that depressed verbal ability may serve to substantially inhibit non-white student achievement in the ISCS curriculum.

It may be argued that since content, goals, etc., differ for IPS and ISCS, direct comparisons may yield uninterpretable results. This could explain the fact that studies making a direct comparison between ISCS and IPS could not be found. Teats (1972) reported a comparison of ISCS and non-ISCS student achievement at the ninth grade level using Piaget-type tasks as criteria. There were no significant gains for both ISCS and IPS students in achievement using the STEP (science subscore) as criterion; no comparison between IPS and ISCS-Level II was attempted. This lack of comparative data suggests the need for data-based conclusions prior to the implementation of either ISCS-Level II or IPS, particularly when the issue of the poor verbal ability of white and non-white students exists, and the criterion is facility with process skills rather than the learning of subject matter.

In general, the research literature overwhelmingly favors male achievement over female achievement in science courses. This finding is not limited to the United States; it has been corroborated on a world-wide basis (Featherstone, 1974).

Method

Statement of Problem

This study was conducted to investigate the following hypotheses: student performance as measured by the Process Of Science Test will be significantly higher for -

1. Students completing ISCS-Level II science than for students completing IPS science when selected individual learner characteristics are controlled statistically;

2. Non-white students completing IPS science than for non-white students completing ISCS-Level II science when selected individual learner characteristics are controlled statistically;

3. Male students completing ISCS-Level II science than for female students completing the same curriculum when selected individual learner characteristics are controlled statistically;

4. White students completing ISCS-Level II science than for non-white students completing the same curriculum when selected individual learner characteristics are controlled statistically.

Instruments

Since the emphasis of both these science curricula appears to be focused on learning processes and methods of interpreting data rather than learning concrete facts, the test instrument was chosen to measure students' facility with selection of processes of science rather than their knowledge of science. The instrument which consists of 40 multiple choice items designed to provide a standardized estimate of a student's understanding of science and its methods is called the Process Of Science Test (POST). It was developed by the BSCS Curriculum Study group to appraise a student's understanding of general scientific processes and scientific reasoning ability.

The POST correlates closely with the Verbal Reasoning and Numerical Abilities Test of the Differential Aptitude Test and has a reliability of .82 for split-half correlation and .72 for test-retest correlation.

Sample

Subjects for this study were selected from the population of eighth grade students attending Gwynn Park Junior High School, Prince George's County, Maryland. All students taking part in this study completed a life science course in the seventh grade.

The assignment of students to different sections of the class was done by computer before the study was conducted through normal sectional scheduling. In this assignment procedure mathematical ability ranking was used. The goal of student assignment is to obtain classes which are relatively heterogeneous on mathematical ability. After the initial scheduling, three sections of 29 to 32 students each were chosen for the experimental group and another three sections of 29 to 32 students each were chosen for the control group. This assignment and selection produced an experimental sample of 88 students (67 white, 21 non-white - 47 male, 41 female) and a control sample of 79 students (65 white, 14 non-white - 41 male, 38 female). These samples were used as a pool from which the final sample was chosen. A nonsignificant F-ratio across treatment group (Table 5) indicates equivalence of experimental and control groups on math scores.

Tables 1 and 2 present the mean scores for ISCS/IPS sex and race groups on the Verbal, Science, Math, and Abstract Reasoning Subscores of the Iowa Test of Basic Skills. Tables 3 through 6 summarize the analyses of variance on the above four subscores using a treatment by race (2x2) design. In all cases, a significant main effect favoring whites was noted. In only one class (science) was a treatment group effect noted, favoring the ISCS group.

When similar treatment by sex analyses were run with these variables (data not reported here) no significant differences existed. Thus, the only major pre-experimental difference present was across racial composition.

Design

This ex post facto, intact group study was carried out using a post-test only design with data from school files used to investigate pre-experimental group equivalence.

The assignment of students to either one of two treatment groups (IPS or ISCS) was done by way of normal sectional scheduling with those students assigned to teacher A being the IPS group and those assigned to teacher B being the ISCS group.

To determine if the treatment groups were equivalent prior to the study, ITBS subscores measuring verbal, science, math and abstract reasoning abilities were obtained from the school's test files. The Iowa Basic Abilities subtest scores along with the POST scores were used to form a data pool from which final sample selection was made by random selection.

A 2x2 factorial design was employed to test the several hypotheses presented simultaneously. Since the literature review pointed out a possible interaction of verbal ability and achievement in the case of the non-white student and since race related differences were noted after class sections were formed, two possible procedures of statistical analysis were suggested: (1) analysis of variance; to assess group equivalency and to determine if any significant post-experimental differences were present and, (2) analysis of covariance; to control for the effect of individual learner differences on the criterion.

Since the analysis of covariance program used requires a data cell of equal size it was necessary to randomly select scores from the data pool to produce cells with equal sizes. This selection produced a cell of 28 students for the 2x2 factorial design for treatment and sex (total sample - 56 male, 56 female).

The same procedure was followed for the 2x2 factorial design for treatment by race producing a cell of 12 students each (total sample - 24 white, 24 non-white).

The criterion for this study was student acquisition of scientific process skills as measured by the Process Of Science Test. The covariates used were verbal, science, mathematics, and abstract reasoning ability subscores from the Iowa test battery. The null hypotheses was treated at the 0.05 level of significance.

Findings

The results of analysis of variance to test for pre-experimental group equivalence on treatment x sex showed no significant differences between groups on verbal, science, math, or abstract reasoning ability; the treatment groups were therefore considered equivalent. Group means for this analysis by cell can be found in Table 1.

Analysis of variance to test pre-experimental group equivalence on treatment x race (Tables 3-6) showed that significant differences existed between racial groups in pretest criteria:

1. Verbal ability - white students scored significantly higher in verbal ability than non-white students.

2. Science ability - white students scores significantly higher in science ability than non-white students.

3. Math ability - white students scored significantly higher than non-white students.

4. Abstract reasoning ability - white students scored significantly higher in abstract reasoning ability than non-white students.

It was therefore concluded that the white and non-white samples were not randomly drawn from the same population.

When the analysis of variance was performed with POST scores as criterion and treatment and sex as variates, no significant treatment or sex differences were found; the treatment x sex interaction was also nonsignificant. However, when the analysis of variance was performed with POST scores as criterion and treatment and race variates, a significant racial effect was observed. Separate analysis showed that the white student scored significantly higher than the non-whites. Neither the treatment effect nor treatment x race interaction were significant.

After the initial analysis of variance was performed, analysis of covariance was carried out to see if any of the selected control variables would cause the null hypotheses to be rejected. The results of the analysis of covariance show that there were no significant differences between treatment groups, sex groups or racial groups when verbal ability, math ability, science ability and abstract reasoning ability are controlled statistically. The ANCOVA summary tables for three of these four analyses have not been included in this report.

Conclusions

The nonsignificant difference between males and females on facility with processes of science is interesting since numerous research studies show a significant difference between sexes where science related learning is involved. Four hypotheses may be put forth to explain this null result. First, one may hypothesize that both IPS and ISCS compensate for differences in science learning between sexes. Second, research shows that while females score significantly higher than males on tests of general verbal ability (Terman and Tyler, 1954) males outscore females on word problem solving tests (Tyler, 1965). Perhaps any verbal problem solving advantage to males is compensated for by general verbal ability of females in curricula where both factors are present. This study would tend to support a third hypothesis (variabilities within sexes is so large as to overshadow variabilities between sexes) (Tyler, 1973) in that pretest scores for verbal, science, math, and abstract reasoning ability were equivalent across sex groups (Fritz, 1973). This study did not generate any evidence to support a fourth hypothesis of male-female sex role identification although there is apriori reason to believe that at about age 14, word problem solving becomes clearly defined as a masculine activity (Poffenberger and Norton, 1963).

The analysis of the criterion score using the ANOVA technique showed a significant difference between the ISCS and IPS group when treatment, race, and treatment x race were analyzed (Table 8). This result suggested the possible rejection of the null hypothesis. However, after analyzing the data using analysis of covariance no significant difference was found between these groups (Table 9). It was therefore concluded that the null hypothesis could not be rejected when individual learner differences were controlled statistically.

It appears that pre-experimental group differences arising from the use of intact groups may have caused this difference between ISCS-Level II and IPS students. When these differences were controlled statistically, ISCS-Level II and IPS students displayed equivalent proficiency with the process skills.

Since there was one significant pre-experimental difference between treatments (Table 4) in favor of the ISCS group and no treatment difference after the courses (on the POST criterion), two hypotheses seem feasible. Either POST scores are unrelated to differences in science ability, or both ISCS-Level II and IPS successfully accommodate for observed differences in science achievement. The results of the study tend to support the latter judgment, although the data are not strong.

Upon examination of the factor of race, it is observed that pre-experimental differences between races (verbal, science, math, and abstract reasoning abilities, Tables 3-6) were noted. Racial differences, favoring whites, were present after the courses, using the criterion of POST scores (Table 8). This post hoc analysis suggests neither ISCS-Level II nor IPS removes racial differences in science processes. Further support for this notion comes from the fact that when analyses of covariance were conducted with POST scores using verbal, science, math, and abstract reasoning abilities respectively (Table 9; Fritz, 1973), race-related differences were no longer evident. Neither ISCS-Level II nor IPS could accomplish what covariance could.

Recommendations

On the basis of student performance on the Process Of Science Test it is felt that the ISCS-Level II and IPS science curricula will both allow the student to reach a reasonable level of competence in understanding the processes of science since at the eighth grade level the students in the present study attained a mean score of 17.75 (ISCS) and 16.85 (IPS) while the national norm for the POST at the tenth grade level is 22.

The implications and limitations of this study suggest many possible areas for future study such as:

1. Are there performance differences between students who have had Level I and Level II ISCS and students having another science in seventh grade and IPS in eighth grade?

2. Is there a teacher effect present?

3. Are there any significant gains in understanding science processes taking place in either the ISCS or IPS classes?

4. Do ISCS and IPS accommodate for prior science ability?

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Table 1

Group Means for Verbal, Science, Math, and Abstract Reasoning Ability Broken Down by Cell

Cell	Verbal	Science	Math	Abstract Reasoning
ISCS - Male	42.32	56.21	42.21	56.28
ISCS - Female	41.32	49.96	42.64	51.29
IPS - Male	43.00	47.92	38.89	48.75
IPS - Female	47.92	41.32	43.11	46.25

Table 2

Group Means for Verbal, Science, Math, and Abstract Reasoning Ability Broken Down by Cell

Cell	Verbal	Science	Math	Abstract Reasoning
ISCS - White	40.17	56.92	51.25	68.17
ISCS - Non-white	33.83	51.00	36.50	28.67
IPS - White	56.08	49.00	42.83	52.83
IPS - Non-white	20.83	21.75	26.50	36.00

Table 3

Analysis of Variance on Verbal Ability with Treatment and Race Variates

Source of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F-Ratio
Treatment	1	25.52	25.52	0.05
Race	1	5187.52	5187.52	9.36**
Treatment x Race	1	2508.52	2508.52	4.54*
Error	44	24335.92	553.09	

Table 4

Analysis of Variance on Science Ability with Treatment and Race Variates

Source of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F-Ratio
Treatment	1	4144.1	4144.1	6.47*
Race	1	3300.1	3300.1	5.16*
Treatment x Race	1	1365.3	1365.3	0.15
Error	44	28163.0	640.1	

* $p<0.05$
** $p<0.01$

Table 5

Analysis of Variance on Math Ability with Treatment and Race Variates

Source of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F-Ratio
Treatment	1	1017.52	1017.52	1.53
Race	1	2898.52	2898.52	4.37*
Treatment x Race	1	7.52	7.52	0.01
Error	44	29185.92	663.32	

Table 6

Analysis of Variance on Abstract Reasoning Ability with Treatment and Race Variates

Source of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F-Ratio
Treatment	1	192.00	192.00	0.27
Race	1	9520.30	9520.30	13.24**
Treatment x Race	1	1541.30	1541.30	2.14
Error	44	31650.00	719.30	

Table 7

Group Means on POST Test Reported by Cell

Race	ISCS	IPS
White	19.50	17.67
Non-white	16.00	16.35

Table 8

Analysis of Variance on POST Scores with Treatment and Race Variates

Source of Variance	Degree of Freedom	Sums of Squares	Mean Squares	F-Ratio
Treatment	1	58.52	58.52	2.11
Race	1	180.19	180.19	6.51*
Treatment x Race	1	1.69	1.69	0.61
Error	44	1218.58	27.70	

Table 9

Analysis of Covariance on POST Scores with Treatment and Race Variates and Science Ability as Covariate

Source of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F-Ratio
Treatment	1	1226.05	1226.05	2.45
Race	1	49.45	49.45	0.10
Treatment x Race	1	914.86	914.86	1.83
Error	44	21490.79	499.79	